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JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

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RECENT DEVELOPMENTS IN LIGHT-WEIGHT FLOOR AND ROOF CONSTRUCTION

BY BURTIS S. BROWN.*

(Presented at a meeting of the Designers Section of the Boston Society of Civil Engineers, April 8, 1931)

DURING the recent months the building industry in common with other lines of business has been passing through a depression. This condition has afforded time to evaluate the merits of various materials of construction. The leaders of the industry have been "taking count of stock," and many of our ordinary forms of construction have been abandoned and new materials substituted. This paper will discuss a few of these newer types, limiting its scope to the more recent developments in secondary members for floors and roofs, such as:

Steel joists.
Junior beams.
Built-up joists.
Battleddeck floor.

Also, the discussion will include light-weight slabs or deckings, namely:

Gypsum.
Haydite.
Aerocrete.
Porete.

Besides reducing the dead weight of structures, each of these deckings gives insulation properties superior to the older types of fire-resistive materials.

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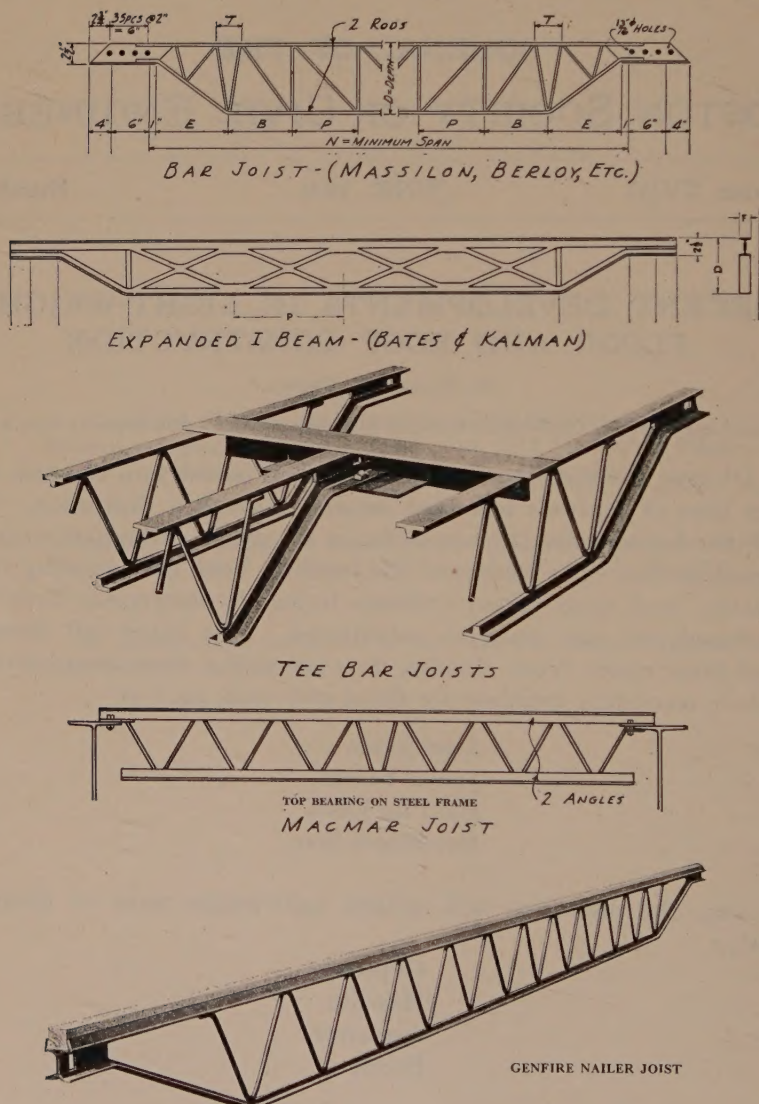


FIG. 1. — TYPES OF STEEL JOISTS

Wood joist and decking was the popular building material for floors and roofs in this country for nearly three hundred years. Then steel beams with brick or terra cotta arches began to be used where fire-resisting materials were required. Next came reinforced concrete for slabs, beams and girders as well as for columns and footings. This material has proved very satisfactory where fire protection is the principal requirement. However, its dead weight is excessive, often amounting to 80 pounds per square foot, and even to 120 pounds per square foot for roofs where the live or snow load to be carried is only 40 pounds per square foot. It is self-evident that the proportion of dead to live loads is out of balance.

The best design for any particular use gives the owner the greatest amount of actual and potential value for the least amount of money. This search for economy in construction does not invite cheapness, for —

Good designs are necessary for better buildings.

Poor designs are never cheap.

It is often said, "An engineer is a designer who can deliver to the public for ONE DOLLAR, what the ordinary citizen would pay TWO to obtain." We must keep constantly in mind that first costs do not alone afford the greatest ultimate economy.

STEEL JOIST

Bar Joist or Open Truss Joist

These floor or roof members consist of fabricated steel sections, supported on masonry walls or on a structural steel frame in a similar manner as wooden floor joists are used. On top of these joists it is customary to place metal lath of the heavier type, or steeltex, occasionally reinforced with rods or mesh, upon which is placed a thin concrete slab. Above this slab is placed any of the various floor finishes, as ter-razzo, granolithic, linoleum, or even wood floor. On the underside of the joists the usual small steel channels are attached, then metal lath is wired to the channels, and finally a plastered ceiling is added, using Portland cement plaster on the more fire-resistive work.

There are many varieties of steel joists on the market. Some are made with a top and bottom chord of round bars, others use structural shapes, such as tees or angles, and still others have special shapes rolled for the fabrication of their products. These two chord members are made into units by single rods for web members welded to the top and bottom chords forming a simple truss of the Warren or Pratt type. These are shown in Fig. 1. Certain other types are made from specially

rolled sections. The webs of these sections are cut and expanded, thus forming trusses. The Bates and Kalman illustrates this variety. Another has a special shaped top chord made to retain a nailing strip. These are used where a wood top flooring is required and it is desired to eliminate the shrinkage of wood.

Steel joists first appeared on the construction material market about 1922. At the present time there are between eight and ten com-

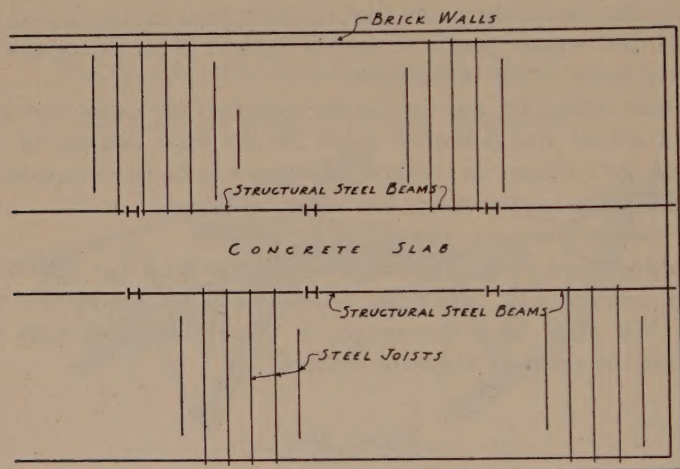


FIG. 2. — LAYOUT FOR SUPPORTS FOR STEEL JOISTS

peting concerns manufacturing this material. The destinies of this branch of the building material industry is watched over by the Steel Joist Institute of Detroit.

Advantages of Steel Joists

1. *Lightness in Weight.* — The weight of a joist to carry a total load of a 100 pounds per square foot on a span of 20 feet and with a spread of 1 foot 8 inches is 107 pounds. A spruce joist for a similar load weighs 175 pounds and a rolled steel channel weighs 230 pounds.

2. *Ease of Running Pipes, Conduits, etc.* — With the ever-increasing complications in the mechanical features demanded by tenants and

owners, the problem of finding space for these necessary evils in building construction continues to tax the designer's ingenuity and skill. With the open spaces between the web members, ample space is available for these.

3. *Reduction of combustible material* is accomplished with steel joists. While these members do not rank as fireproof material, they do reduce the amount of fuel for a fire to feed upon.

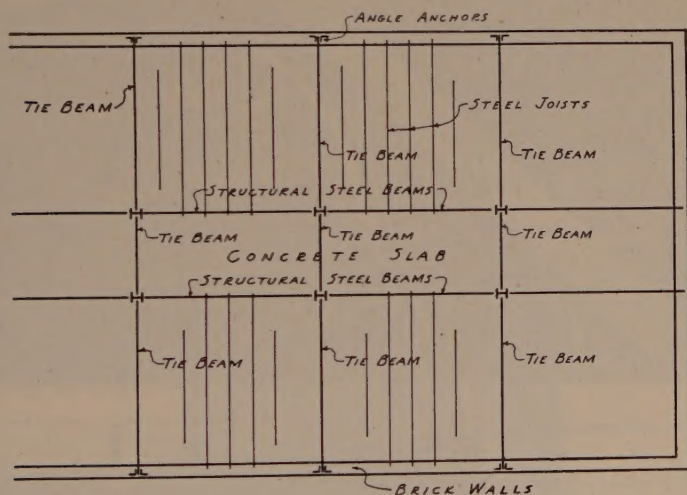


FIG. 3. — IMPROVED LAYOUT FOR SUPPORTS FOR STEEL JOISTS

4. *Shrinkage* is eliminated in this type of floor system, thus removing one of the causes of regret to builders.

Requirements

1. The structural supports for the steel joists must be adequate. Besides choosing joists of sufficient size, the structural steel, reinforced concrete wall or masonry wall must have sufficient strength safely to support the loads. In Fig. 2 is shown the supports for steel joists used in a large hotel in Cambridge. There were no structural steel ties laterally. Cracks developed before the building was completed. A conservative engineer could not approve this design. Fig. 3 shows how this design might have been improved with a small percentage increase in cost.

2. End supports should be positive. On masonry ends a wall anchor should be used, as shown in Fig. 4, while on structural beams a satisfactory attachment is shown in Fig. 5.

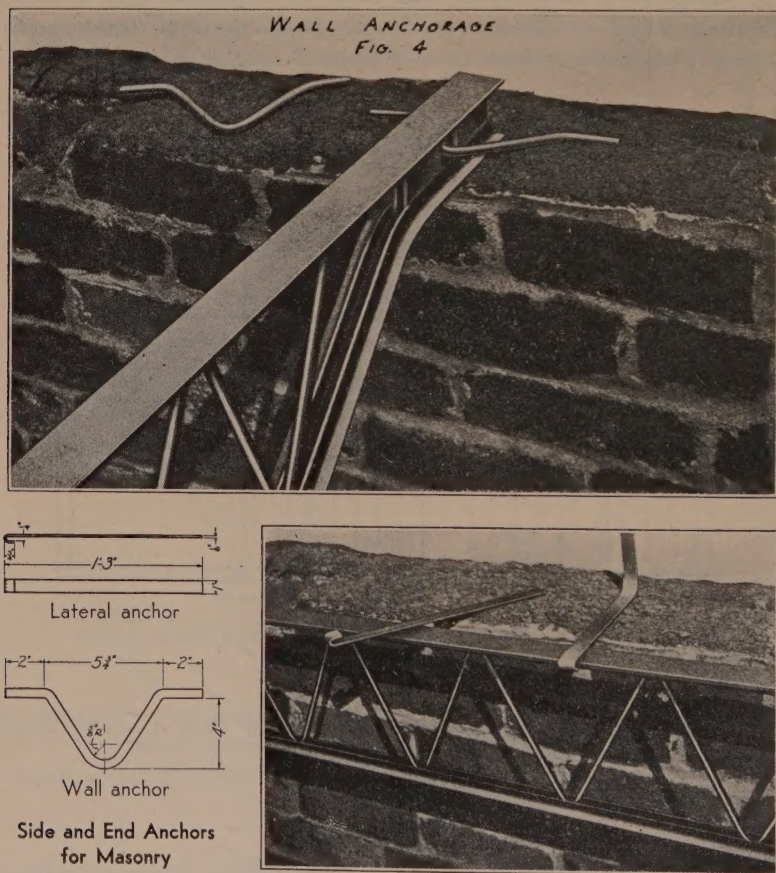


FIG. 4. — WALL ANCHORAGE FOR STEEL JOISTS

3. Bridging is one of the debated details of this material. Five different methods of providing for this stiffening are shown in Fig. 6.

4. Depth of joists for light-weight loadings of different spans are recommended, as follows:

SPANS										Depth of Joists
Up to 16' 0"	.	.	.	.	.	.	.	.	.	8 inches
16' 1" to 20' 0"	.	.	.	.	.	.	.	.	.	10 inches
20' 1" to 24' 0"	.	.	.	.	.	.	.	.	.	12 inches
24' 1" to 28' 0"	.	.	.	.	.	.	.	.	.	14 inches
28' 1" to 32' 0"	.	.	.	.	.	.	.	.	.	16 inches

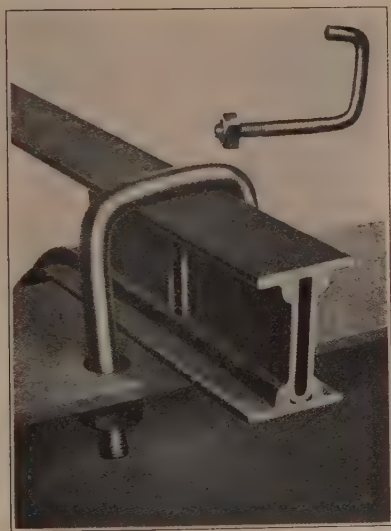


FIG. 5.—ANCHORAGE FOR STEEL JOISTS
AT STRUCTURAL BEAMS

Limitations

There seems to be a wide difference of opinion in regard to the allowable height of building where steel joists are used. Some designers say three stories should be the maximum height of a building using steel joists, while actual buildings have been constructed to a height of 35 stories. Mr. Burton, consultant for the Steel Joist Trade, told one of the committees which is revising the local Building Law that he thought six or seven stories sufficient height for a building with steel joist floors. He expressed the opinion that wind bracing for a tall building could be

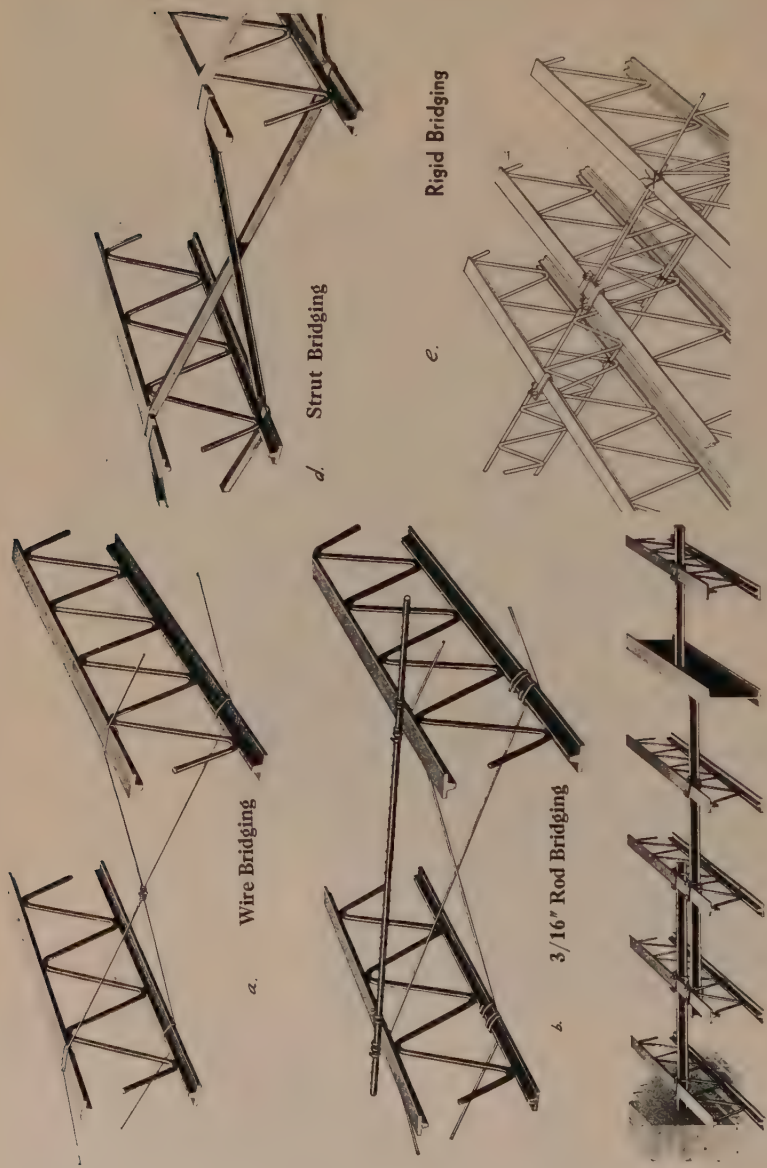


FIG. 6. — METHODS OF BRIDGING FOR STEEL JOISTS

bought for less money in the form of thick monolithic floors than with special bracing necessary with loose members, as steel joists.

Steel joists should not be used for occupations where there are heavy, moving loads, as in a garage or in a factory.

Fireproofness

Steel joist construction is now recognized by the Insurance Rating Bureau as possessing merit in fire retarding. It does not receive the advantages of the so-called fireproof building, such as a reinforced concrete structure. However, where good workmanship is evident in the placing, bridging and anchoring of the steel joists, together with a well-built reinforced concrete slab and a metal lath and cement plaster or gypsum plaster ceiling, the Rating Bureau will give a one-hour rating for this material.

Disadvantages

One of the criticisms of steel joist construction has been the lack of rigid bridging. The first bracing used consisted of wires crossed in X fashion from the top chord of one joist to the bottom chord of the adjacent joist. As actually installed, this wire bridging was not worth the time to place it. It was an insult to trained men in the construction business to ask them to approve such a makeshift. One of the steel joist concerns has evolved a rigid bracing that is really worth while. It is shown in (d) Fig. 6. It consists of two small-sized channels (about 1 inch deep) crossed X shape, and at each of the four ends a notch is made to engage in the edge of the flange of the top and bottom chords of adjacent joists. Another method is to place a light-weight steel joist at right angles to the main carrying joists, passing it through the space between web members and clamping it rigidly to the main truss (see (e) Fig. 6).

Floors of steel joists make a taller building, due to the extra height where the joists set on top of the main carrying steel beams. Flush top construction does not seem possible without considerable extra expense. Two and one-half inches are lost at each floor. This means extra weight of walls without additional return.

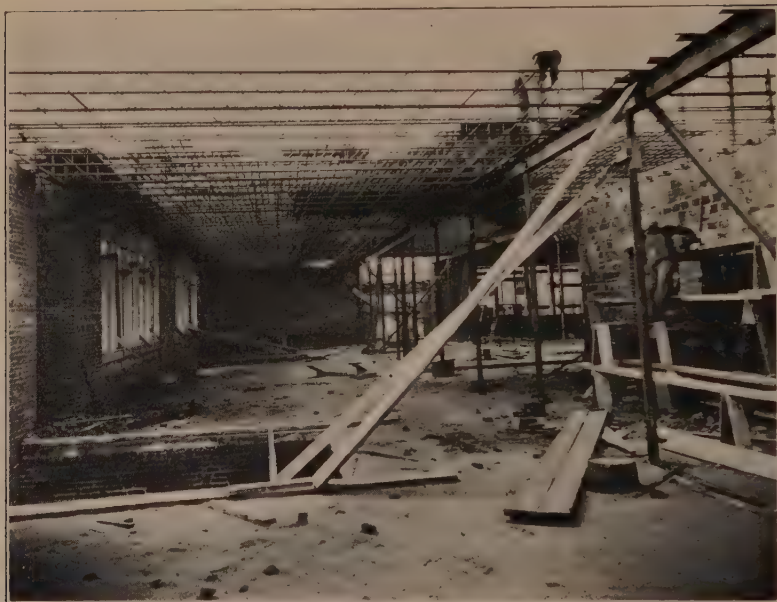


FIG. 7.— STEEL JOISTS IN SCHOOL BUILDING



FIG. 8.— STEEL JOISTS IN SCHOOL BUILDING, TOP VIEW

Use

In Figs. 7 and 8 are shown two views of a school building at Manchester, N. H.

JUNIOR BEAMS, OR LIGHT-WEIGHT STEEL BEAMS

These shapes are among the newcomers in the structural field. They are made from hot rolled steel, varying from 6 to 12 inches in depth. These beams are about one-third the weight of standard steel



FIG. 9. — COMPARISON OF JUNIOR BEAMS
WITH STANDARD I-BEAMS

shapes, and have one-third the strength of the standard shapes. The thickness of webs varies from one-eighth to three-sixteenths inches. In Fig. 9 a junior beam is shown in comparison with a standard beam of the same depth. Tie rods must be placed at frequent intervals to stay the beams laterally. There is difficulty in making riveted connections to the flanges, due to the narrow width. Copper bearing steel of structural grade is used for junior beams. The reason for the copper content in this material is to retard corrosion in the thin webs and flanges. The shapes are rolled both by Jones & Laughlin Steel Corporation and by the Bethlehem Steel Company. They form an acceptable type of construction for conservative designers where close spacings of secondary members are necessary for the type of decking or slab to be used.

Fig. 10 shows a table giving a comparison of junior beams with minimum weight standard beams. Here are shown the differences in weight, size and strength.

COMPARISON OF J+L JUNIOR BEAMS WITH STANDARD BEAMS												J+L LIGHT WEIGHT CHANNELS		
SIZE	6"		7"		8"		9"		10"		12"		10"	12"
PROPERTIES	J+L	J+L	J+L	J+L	J+L	J+L	J+L	J+L	J+L	J+L	J+L	J+L	J+L	J+L
WEIGHT	12.5	4.41	15.3	5.40	18.4	6.54	21.0	7.40	25.4	8.96	31.0	11.74	15.3	9.0
AREA - Sq. IN.	3.61	1.30	4.43	1.61	5.34	1.92	6.32	2.20	7.30	2.64	9.26	3.43	4.47	2.33
BREADTH OF FLANGE	3.93	1.04	3.66	2.00	4.00	2.20	4.33	2.30	4.66	2.69	5.00	3.06	2.6	1.5
THICKNESS OF WEB	.230	.114	.250	.126	.270	.135	.290	.145	.310	.155	.410	.175	.24	.16
SEC. MODULUS X-X AXIS	7.27	2.42	10.34	3.45	14.22	4.65	18.07	5.81	24.42	7.70	58.91	12.01	13.4	6.1
COEF. STR.	93200	23074	124100	41825	170700	53817	276400	67277	273000	93369	504300	146000	163600	75000
MAX. MOM. TOL.	308000	3610	1067000	62137	2561000	93726	3396000	146371	4596000	140354	10450000	216137	2407000	1000000

FIG. 10

In Fig. 11, junior beams are shown in a nurses' home, together with steel floor beams and Lally columns.

FIG. 11. — JUNIOR BEAMS USED FOR
SECONDARY FLOOR MEMBERS

BUILT-UP JOISTS

These joists are in the strip steel group, as they were originally made from that material. Both types described here are declining in popularity. They lack the required feature of steel joists, namely, the open spaces between web members, through which pipes can be run. With such small gauge metal the joists are much reduced in strength from a small amount of corrosion. This necessitates the members being protected from the weather by superior painting or kept under cover during erection.

Plate Girder Joists

This type of light-weight secondary members is made by welding four angles to a rectangular sheet of steel. This combination forms a



FIG. 12. — BUILT-UP PLATE GIRDER JOIST



FIG. 13. — DOUBLE CHANNEL JOIST

miniature plate girder, shown in Fig. 12, made of a web of steel plate from .07 to .13 inch thick spot welded to four angles of the same material.

This material is available in sizes from 6 to 14 inches in depth, and flange widths from $2\frac{1}{2}$ to 4 inches. They have a slightly greater section modulus for a given depth than rolled junior beams.

As you will see at a glance, the distribution of metal is not ideal. The metal in the vertical portions of the angles would be more effective in the flanges.

Double Channel Joists

These members are made from steel plates, first formed into the shape of a channel, then two of these channels have their webs spot welded to form an I beam shape, shown in Fig. 13. They are made in depths of 4 to 12 inches.

BATTLEDECK FLOOR CONSTRUCTION, OR STEEL DECKING

This method of forming a floor is one of the newest on the market. Flat steel plates, varying in thickness from three-sixteenths inch to one-half inch, are laid on top of standard I beams, ranging in size from 3 to 12 inches deep. The joints in the plate come directly over the web of the beam, shown in Fig. 14. With a special welding machine that does rapid work the two plates are welded together and also welded to the top flange of the beam. The welding of the plate to the beam makes an unsymmetrical section, and the neutral axis of the combination is raised above the center of the beam.

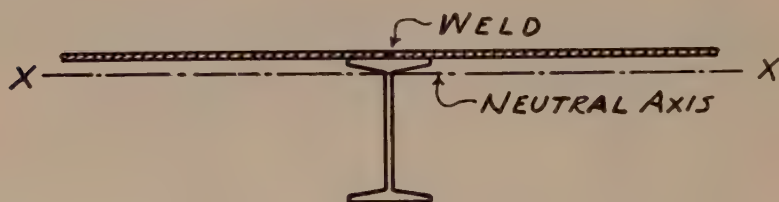


FIG. 14. — BATTLEDECK FLOOR CONSTRUCTION

Advantages of Battledeck

1. Lightness in weight.
2. Ease of erection.

Requirements

1. For use in a heated building, insulation can be used. Also for sound-proofing several acoustic materials are available.
2. Plastered ceiling, if required, may be obtained by first placing specially made precast gypsum slabs having a special flange which locks on the bottom flange of the steel beams. Then the finish plaster coats are applied to the gypsum slab.

Limitations

1. Use best adapted to heavier buildings — those carrying 125 pounds per square foot or over.
2. Any type of floor finish desired can be used on top of the deck.

Use

About 30 buildings have been built using this method of construction, as well as many bridge floors.

The Bureau of Standards is now making an elaborate series of tests on battledeck floors, including load, fire and sound conductivity tests. Costs are not available to any extent for this construction. For floors with 125 pounds per square foot load, the amount of material is approximately 15 pounds per square foot, and at 4 cents per pound for material in place would make the cost 60 cents per square foot. To this should be added the cost of welding amounting to 10 cents per square foot, thus bringing the cost of the bare material in place as 70 cents per square foot. To this must be added material for floor finish and ceiling slabs, if the latter are required.

The American Institute for Steel Construction issues bulletins describing this floor and giving tables of strength.

TABLE I

SECONDARY MEMBERS ON 20'-0" SPAN

COMPARISON OF WEIGHTS AND COSTS

LIVE LOAD 125 #/Sq. Ft.				LIVE LOAD 50 #/Sq. Ft.			
TYPE OF FLOOR	WGT PER Sq. Ft.	COST IN ¢ PER Sq. Ft.		TYPE OF FLOOR	WGT PER Sq. Ft.	COST IN ¢ PER Sq. Ft.	
3" X 12" HARD PINE @ 13" o.c.	10	33		2" X 12" HARD PINE @ 16" o.c.	5½	17	
12" STEEL JOISTS @ 15" o.c.	5½	26		10" STEEL JOISTS @ 16" o.c.	4	19	
12" J+L BEAM @ 22" o.c.	6	31		11" J+L BEAM @ 30" o.c.	4	18	
6 X 14 CONCRETE 1-8" + 1-2" ROOS	38	51		5" X 12" CONCRETE 2-2" ROOS	20	46	

THE ABOVE WEIGHTS AND ESTIMATED COSTS ARE FOR THE STRUCTURAL MEMBERS IN PLACE; WEIGHT AND COST OF FLOORING AND CEILING ARE NOT INCLUDED.

Table I shows a comparison of cost for different types of secondary members on a 20-foot space and for 50 and 125 pound per square foot live loads.

GYPSUM

For the use of slab or decking in light-weight floor and roofs, gypsum has become a much used building material. This product was used by the ancients in their temples, and it has stood the "test of time" to a remarkable degree. Since the World War there has been a tremendous growth in its use as a building material.

Gypsum is composed of one part of calcium sulphate and two parts of water, represented by the chemical formula $\text{CaSO}_4 \cdot 2(\text{H}_2\text{O})$. Calcina-

tion removes approximately $1\frac{1}{2}$ parts of water, leaving $\text{CaSO}_4 \frac{1}{2}(\text{H}_2\text{O})$, which is known as calcined gypsum, or plaster of Paris. (The latter popular name owes its origin to the existence of large deposits at Montmartre, which is near Paris).

There are two grades of gypsum used in construction: one is known as "first settle" gypsum, which is calcined at about 330°F . This temperature is reached in about two hours. When gypsum is being calcined it boils or surges violently in the kettles. This is caused by the steam which is rapidly given off. When the temperature reaches 320° to 330°F ., the material settles down to a quiescent state. If the calcination is stopped at this point, the resulting product is known as "first settle" gypsum. However, if the calcination is continued, the boiling begins again and at a temperature of approximately 400°F ., the material settles a second time, and the result is "second settle" gypsum, — a denser, stronger product and of lower consistency.

Deposits of natural gypsum are found in many States of the Union and many foreign countries. Much of the raw product used in Boston and vicinity comes to the gypsum plant beside the Chelsea Bridge, Charlestown, by boat from Nova Scotia. The same source supplies the large plant at Portsmouth, New Hampshire. At other plants, gypsum is produced from the by-product from certain chemical factories.

Advantages of Gypsum

The lightness of gypsum is one of its chief advantages. It weighs 48 pounds per cubic foot, which is about one-third the weight of concrete and about the same as hardwood. This favorable feature is reflected throughout the entire structure, as it means smaller beams, columns and footings, added to the less cost of freight, haul, hoist, erection and interest on investment. Frequently an unprofitable building can be pulled out of "the red" by the increased revenue from one or two additional stories made possible with the less dead weight of gypsum in comparison with any other structural material, permitted in fire-resisting construction.

While light in weight, gypsum has adequate strength for structural purposes. The ultimate compressive resistance of gypsum varies from 500 to 1,800 pounds per square inch, depending on the variety of gypsum used. The efficiency of gypsum is indicated by the favorable results of large size load tests amounting to ultimate uniformly distributed load of over 500 pounds per square feet.

The splendid insulating properties of this material must be men-

tioned. Much more attention is now given to the prevention of loss of heat and cold than formerly.

The sound absorption qualities of gypsum add to its favorable consideration in many structures. The demand for quieter quarters is constantly heard.

The excellent fire-resistant qualities of gypsum construction has been attested by numerous fire, load and water tests, dating from 1897 until the present time. As a practical fire test, let me describe a very stubborn fire in the five-story warehouse of the Seaboard Warehouse Corporation in New York City. Area of each floor, 8,000 square feet. Structural floors were of gypsum, 4 inches thick, supported on steel beams and girders, the fireproofing being gypsum. The contents of the warehouse consisted of sulphur in bags, wool, hemp and jute in bales. When the fire department arrived, the tops of the jute bales were blazing at the rear portion of the first floor. The water played on the jute bales caused them to expand, and this in turn pushed out the north wall of the building a maximum of 40 inches at the second floor, and allowed the fire to spread to the upper floors. The walls were much out of plumb. The fire continued intermittently for ten days. During the progress of the fire the sulphur on the second floor was heated or burned to the extent that it flowed over the entire area of the floor to a depth of about 2 feet.

The original load on the floors was in excess of the capacity. Then the contents absorbed a great deal of water from the fire streams, making a load condition much in excess of the designed loads. Even with all of the above disadvantages, the New York Board of Fire Underwriters issued the following report:

The floor system performed its function adequately as regards fire resistance; . . . the floors, panels, girders and beams resisted the fire well, considering the intense heat due to long-continued high temperatures from the burning jute and sulphur, as well as the other merchandise with which the floor was loaded.

In the rehabilitation of the building it was found necessary to replace only a few of the floor panels on the north and west sides, where several panels were pushed out of line by the expansion of the jute. The remainder of the floor panels were restored by merely patching the under side with plaster, and this building is still in use, being occupied as a paper warehouse by the "New York Times."

Requirements

A large percentage of the buildings where gypsum is used structurally are steel frame structures. Frequently gypsum is used in connection with steel joists. There are two equally satisfactory methods of constructing gypsum slabs: (1) poured-in-place and (2) precast. Besides, there are two systems of reinforcing, namely, the suspension type and the reinforced system.

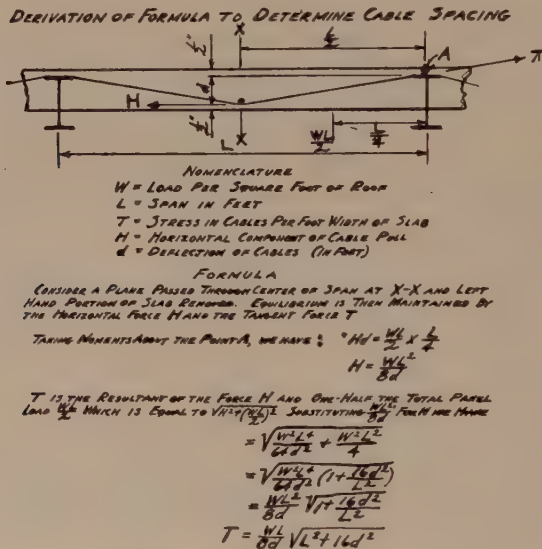


FIG. 15. — STRESS ANALYSIS, SUSPENSION TYPE OF SLAB

1. The "poured-in-place" method uses the suspension system of reinforcement, — cables composed of two No. 12 gauge, cold drawn galvanized steel wires twisted together. These cables are spaced from $1\frac{1}{2}$ to 3 inches apart, depending on the span and the amount of load to be sustained. The gypsum serves as material to transfer the load to the cables, much as a mattress transfers weight upon it to a bed spring. These cables carry the entire load. They must be anchored securely at each end, by means of bent straps, to the structural steel wall members. The cables are put in uniform deflection and tension by means of a $\frac{5}{8}$ -inch round deflection rod at midspan. In Fig. 15 is given the stress analysis of the suspension type of slab.

In the cables, a working stress of 20,000 pounds per square inch is used. The gypsum fiber concrete used in the poured-in-place suspension system is composed of $87\frac{1}{2}$ per cent calcined gypsum and $12\frac{1}{2}$ per cent wood chips or fiber by weight.

Another calculation necessary in a suspension slab is the horizontal thrust on the structural steel wall members to which the cables are attached. Usually it is necessary to add steel diagonal bracing in each end bay. This is an extra cost which should be charged to this system when making economic studies of various systems. The first step in the installation of a poured gypsum suspension floor or roof is the erec-



FIG. 16. — FLOOR OR ROOF SLAB OF GYPSUM

tion of the forms or centering. This form work is similar to that used in reinforced concrete construction. Next, the steel cables are placed in position, anchored at each end, the deflection rod secured at midspan and the gypsum fiber mixture is poured in place and brought to a uniform surface. The mixture dries in about fifteen minutes, so it can be walked upon and the forms removed within the next twenty-four hours. The speed of the work of placing gypsum is remarkable when one thinks of the slow drying of other poured-in-place materials. With the most adverse condition of loading, the total design load as determined by the suspension principle does not set up bond, shear or bearing stresses in excess of those that the gypsum fiber concrete can safely carry with an adequate factor of safety, and so these stresses do not have to be calculated in the suspension system. Instead of erecting temporary

wooden forms, it has been suggested to use a permanent gypsum board form for roof construction. The gypsum board is left in place as the under side of the roof, and it is supported by light rails or tees, as sub-purlins spaced $32\frac{1}{2}$ inches o.c., to permit a 32-inch width of gypsum wall board to be used. The writer believes this is a "makeshift construction," and does not recommend its use.

2. The "*precast*" gypsum slabs or tiles are manufactured of neat "*second settle*" gypsum. In this construction the gypsum acts structur-



FIG. 17. — CEILING SLAB AND HANGERS

ally, or, in other words, it is designed by the accepted formulas for the design of reinforced concrete as recommended by the Joint Committee on Standard Specification for Concrete and Reinforced Concrete, using the appropriate working stresses for gypsum. Electrically welded galvanized wire is used for the reinforcement. These precast units of gypsum are known as "short spans" where the span is 30 inches or less. They are from 2 to 3 inches thick. The floor or roof slab is shown in Fig. 16. The ceiling slab and hangers are shown in Fig. 17.

The longer span units are used up to and including 7-foot span, but then the suspension system must be used. Long span roof slabs are

shown in Fig. 18. This means connecting the cables in adjacent slabs and anchoring the cables to the wall beams which in turn must be strengthened with diagonal bracing.

The particular advantage of the use of precast slabs lies in the ease of handling, the fact that slates and ornamental tiles can be nailed directly to them, and the ability to cut the tile easily to fit around dormers, hips, valleys, etc. In special cases tile of various sizes may be secured to accommodate the situation, as in the case of the Harkness Memorial (Yale Quadrangle), New Haven, Connecticut, where special tile spanning from purlin to purlin of various shapes was provided. In the recent development of the steel joists and junior beam secondary



FIG. 18. — LONG SPAN ROOF SPANS, GYPSUM SLAB

members, it has been desirable to secure a light-weight floor and ceiling slab to conserve dead load. Consequently, precast gypsum floors and ceilings have been developed, and they lend themselves admirably to this type of construction. The floor slabs are $2\frac{1}{2}$ inches thick, roof slabs 3, $3\frac{1}{2}$ and 4 inches thick, and the ceiling slabs 2 inches thick, the ceiling being suspended. Naturally, in the precast system no forms are required, the floor tile spanning from joist to joist and the ceiling tile hung from the joists or beams by metal hangers.

The poured-in-place floor and ceiling construction was submitted to a four-hour fire and water test in 1926 and in 1930, and passed both tests for the New York City Building Department. The insulating properties of the gypsum may be well indicated when it is noted that

while the temperature of the fire was over 1,700° F., the temperature at the bottom of the steel floor channels was only 205° F.

Several important tests have been made at the University of Illinois by Prof. W. A. Slater, also at Columbia University and the United States Bureau of Standards.

Stresses

Without extended discussion, the following stresses are for the designer's use:

	Neat Gypsum as used in Precast Tiles	Gypsum Fiber containing not more than 3 Per Cent Fiber	Gypsum Fiber not more than 12 Per Cent Fiber
Ultimate stress (pounds per square inch) . . .	1,800	1,000	500
Modulus of elasticity (pounds per square inch) . .	1,000,000	600,000	200,000
Ratio: $\frac{\text{Mod. of elas. of steel}}{\text{Mod. of elas. of gypsum}} = (n)$. . .	30	50	150
Safe designing stresses:			
Extreme fiber stress in compression in flexure (pounds per square inch)	350	220	125
Bond stress	40	30	30
Shearing stress	30	25	20

Limitations

The structural use of gypsum is limited to short span work (under 8 feet center to center of supports). It is used for slabs only and not for beams.

Disadvantages

In the suspension system it is difficult to make alterations, such as cutting an opening for a new stairway or a skylight after construction is once completed, as the anchorage of the cables is difficult to make.

Special Uses

In cases where it is especially desirable to avoid the occurrence of condensation, or "sweating" and dripping where moist air conditions may occur, gypsum roofs are especially adaptable.

In numerous classes of manufacturing plants, power plants, forge shops, foundries, roundhouses, etc., where sulphur dioxide gas is com-

monly encountered, gypsum roofs are particularly suited to the use. These locations are very often subjected to very severe acid conditions when in combination with high humidity. Most structural materials are readily and rapidly attacked by sulphur dioxide gas, resulting in disintegration, but authentic tests upon reinforced gypsum roof constructions indicate that under continuous subjection to sulphur fumes the gypsum mass actually increases in strength.

Theatres, auditoriums, churches and similar structures, where a light-weight roof is desired to assist in lessening the dead load on truss construction, lend themselves well to gypsum roof constructions.

Users of gypsum should be cautioned to specify long nails to attach slates, tile or shingles to gypsum roofs. Copper, bronze or galvanized nails may be used. The success with which slate has been attached to precast gypsum at the new Harvard dormitories, attests its value as a roof decking where a pitch roof is desired.

For precast gypsum slabs a unique use should be mentioned, that is, in suspended ceilings to separate different occupations. Some building codes specify such separation, and in alteration work this is difficult to accomplish, due to small head room. These precast slabs make a very satisfactory solution for this problem.

HAYDITE

Another recent development in feather-weight concrete is Haydite. This is an aggregate made by burning under a patented process certain earths or rocks. It is marketed in two sizes and can be used to replace either the fine or the coarse aggregates in the ordinary mix of concrete. Frequently, local sand is used with regular commercial Portland cement and coarse Haydite to make up the three elements for a batch of concrete. Again, if still less weight is desired, fine Haydite is substituted for the sand. Either mixture produces the full strength of concrete obtained when using natural aggregates, besides giving a far more fire-resisting material.

Manufacture of Haydite

After crushing to the proper size shale rock, ordinary clay or shale, this material is conveyed to a rotary kiln, about 60 feet long. The heat is low at the entering end of this revolving cylinder. As the material passes along, the heat becomes greater and the outside of the globules are seared over, forming a casing which traps the gases that expand when the heat becomes maximum. This produces a highly vesicular,

light-weight mass, as shown in Fig. 19. On leaving the kiln the clinker is allowed to cool, then it is crushed, screened and graded to the desired sizes. Each of these processes — namely, burning, crushing and screening operations — are at all times under perfect control, and the product is very uniform.

Properties of the Material

The fine Haydite, "A" size, material will pass through a $\frac{3}{16}$ -inch round hole screen. The coarse size, or "C" size, will be retained on a $\frac{7}{32}$ -inch screen and pass a $\frac{3}{4}$ -inch screen.

There are two types of mixtures: (1) "C" Haydite concrete, made from cement, natural sand and coarse "C" Haydite; (2) "All" Hay-

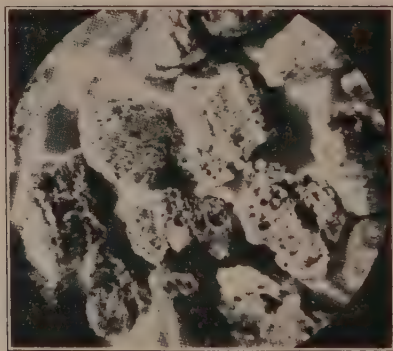


FIG. 19. — DETAIL OF "HAYDITE"

dite concrete, composed of cement, fine "A" Haydite and coarse "C" Haydite.

The aggregate absorb a great deal of water. This makes the application of water cement ratio more difficult than in the case of stone concrete, where a slight error in determination of water content has little effect on the result. An error of 2 per cent in the absorption allowance of Haydite will cause as much as 15 per cent variation in the strength.

Water Cement (Ratio by Volume)	Gallons of Water per Sack of Cement	Compressive Strength (Pounds per Square Inch)
1.10	8 $\frac{1}{4}$	1,500
1.00	7 $\frac{1}{2}$	2,000
0.90	6 $\frac{3}{4}$	2,500
0.80	6	3,000

TABLE OF HAYDITE CONCRETE

	Weight in Pounds per Cubic Foot	Modulus of Elasticity	Ultimate Compressive Strength for 28-day Cylinders (Pounds per Square Inch)
"C" Haydite . . .	115	2,500,000	1,920 for 1:3:3 mix and 1.29 w.c. ratio. 4,300 for 1:1½:2¼ mix and 0.77 w.c. ratio.
"A" Haydite . . .	98	1,900,000	1,280 for 1:3:3 mix and 1.47 w.c. ratio. 3,700 for 1:1½:2¼ mix and 0.88 w.c. ratio.

This low modulus of elasticity makes for a lower neutral axis, and therefore higher percentage of steel for balanced reinforcement. This allows a reduction in amount of concrete needed by 10 per cent in the case of "C" Haydite, and an increase in amount of reinforcing steel by about 6 per cent over that of stone concrete. With "All" Haydite there is 17 per cent reduction in concrete and 15 per cent increase in steel; working stresses in shear and bond may be taken as the same percentage of the ultimate as in the case of concrete.

Haydite aggregates are not available in commercial volume in New England at this time. The only practical use of this material now is in the form of precast roof slabs. These are made 2 feet wide and in lengths up to 6 feet 8 inches. In cross section they are channel-shaped, being 1 inch thick at the center and having on each side a 2 x 2¾ inch rib. They are reinforced with galvanized wire mesh.

Disadvantages

Added expense of material, although there is a final saving, due to reduction in steel frame and lighter foundations.

Advantages of Haydite

1. *Lightness in weight.*
2. *Strength.* — Haydite concrete with equal cement content develops a strength at least equal to concrete made with natural aggregates.
3. *Clean and Pure.* — This material is free from silt or other impurities.
4. *Waterproof.* — Haydite concrete has low absorption, and has no capillary attraction. It can be made absolutely water and oil proof.

5. *Fireproof.* — Superior from fire-resistance point of view.
6. *Nailing.* — By using correct mix, it can be used where nailing is necessary. Nails will hold, if long enough.

AEROCRETE

Aerocrete is an aerated or expanded concrete. It is made with an especially treated cement, together with sand or some other kind of fine aggregate. As usual, water is added for hydration. The ingredients in this special cement separate the water into component gases, and this produces voids, or "air bubbles," in this concrete.

Advantages

1. Reduction in weight and density. It gives a concrete that will float on water.
2. Good insulating value against transmission of heat and sound. In cold storage insulation construction this is a valuable property.
3. Withstands fire better than usual dense concrete.
4. Has many properties of stone and yet woodworking tools can be used to shape it for many uses.
5. Precast aerocrete concrete lumber and panels; also, precast residential work.
6. Fireproofing of steel columns and beams.
7. Cells of aerocrete are impermeable. Since the hydration process is colloidal in nature, there will necessarily be colloidal absorption and rejection of water.

Requirements

1. More water is used than with ordinary concrete.
2. Longer mixing required. From one to three minutes of turning is necessary.
3. From ten to fifteen minutes after water is added expansion begins and proceeds rapidly for half an hour. For the next half hour expansion continues, but more slowly.
4. Some experience is necessary to allow for the correct amount of aeration. If too much of this special concrete is placed in the forms, it can be easily removed before complete hardening takes place.

Use is especially adapted for precast slabs where the loads are low, as in dwelling house occupations spanning between steel joists or junior beams. From 1 to 1.2 per cent reinforcement should be used in the form of steel fabric.

Decided saving in dead weight in fireproofing, in such locations as

between the flanges of steel columns and beams. Local aggregates may be used and the blocks cast at the job, just the sizes required, thus saving freight and hauling, besides giving labor to local workingmen.

Due to the sensitiveness to changes in chemical composition of the cement, and also due to the composition and physical characteristics of the aggregate, it is impossible to give formulæ for the different grades of aerocrete described below, but the proportions of cement, aggregate, chemical regulators and water must be determined for each locality.

TABLE OF WEIGHTS, STRENGTH AND USES OF AEROCRETE

[Modulus of Elasticity, 600,000.]

NAME OF MIXTURE	Weight per Cubic Foot in Pounds	Ultimate Compressive Strength (Pounds per Square Inch at 28 Days)	Use
Heavy weight aerocrete .	70 to 80	800	Where building department requirements are severe.
Structural aerocrete . .	55 to 65	600	Structural purposes, insulation value medium.
Intermediate aerocrete . .	50	300	Partitions, furring, fireproofing, etc.
Insulating aerocrete . .	55	—	Good insulation.
Feather-weight aerocrete .	30	—	Floor filling.

Cost

It has been impossible to obtain any costs for this new type of concrete because of the varying factors. It is a patented process.

Tests

This material has been tested at Columbia University for physical properties and also given a regular fire and water test with such satisfactory results that approval was obtained by the New York authorities for precast slabs. Heat transmission for 3-inch thick partition block is 0.311, thus being lower than wood or gypsum and one-eighth that of concrete.

Disadvantages

In the lighter grades, nails driven into the aerocrete will not hold. Nails will hold in the structural grade.

Difficulty of getting correct mixes with so many variables.

PORETE

Porete is a feather-weight Portland cement concrete with many of the properties of Aerocrete. The manufacture of Porete is by the Bubblestone process, — a method which has been on the market for over four years. To produce a better concrete of this type, a new type of mixer has been evolved where the ingredients are not only mixed, but, in addition to this, they are beaten up into a mass, producing a foamy, jelly-like slurry of aerated concrete. Because of the positive

TABLE II
FLOOR SYSTEMS ON 6'-0" SPANS

LIVE LOAD 125#/Sq. Ft.			LIVE LOAD 50#/Sq. Ft.		
TYPE OF FLOOR	WGT. PER Sq. Ft.	COST IN ¢ PER Sq. Ft.	TYPE OF FLOOR	WGT. PER Sq. Ft.	COST IN ¢ PER Sq. Ft.
2" HARD PINE PLANK	7	22	2" SPRUCE PLANK	5	16
4" TR. STONE CONCRETE $\frac{3}{8}" \text{ @ } 0'$ $\frac{3}{8}" \text{ @ } 18'$	48	38	3" TR. STONE CONCRETE $\frac{3}{8}" \text{ @ } 10'$ $\frac{3}{8}" \text{ @ } 18'$	36	34
4" TR. POURED-IN-PLACE GYPSUM CABLES $1\frac{1}{2}" \text{ @ } 20'$	16	48	4" TR. POURED-IN-PLACE GYPSUM CABLES $2\frac{1}{2}" \text{ @ } 20'$	12	45
2 $\frac{1}{2}"$ PRECAST GYPSUM + 2" CEILING SLAB	21	53	2 $\frac{1}{2}"$ PRECAST GYPSUM + 2" CEILING SLAB	21	53
5" CINDER CONC. SLAB $\frac{3}{8}" \text{ @ } 12' + \frac{3}{8}" \text{ @ } 18'$	40	39	4" CINDER CONC. SLAB $\frac{3}{8}" \text{ @ } 10' + \frac{3}{8}" \text{ @ } 18'$	32	36
4" TR. HAYDITE $\frac{3}{8}" \text{ @ } 0'$ SLAB $\frac{3}{8}" \text{ @ } 18'$	32	40	3" TR. HAYDITE $\frac{3}{8}" \text{ @ } 10'$ SLAB $\frac{3}{8}" \text{ @ } 18'$	24	37

THE ABOVE WEIGHTS AND ESTIMATED COSTS ARE FOR THE STRUCTURAL MATERIAL IN PLACE. NO ALLOWANCE HAS BEEN MADE FOR FINISH FLOOR OR CEILING, NOR FOR THE EFFECT ON THE SUPPORTING FRAME AND FOUNDATIONS OF THE VARIATION IN HEIGHT. IN THE CASE OF THE POURED FLOORS, THE COSTS INCLUDE FORMS.

control by this machine and the accurate aeration, the resulting porosity or weight of the desired concrete can be predetermined very exactly.

One of the recommended uses for this kind of floor is with steel joists, and the bottom of the Porete ceiling throughout is at a distance below the joists of the required fireproofing. This gives a level ceiling for plastering, if the latter is desired; but if sound absorption is required, an excellent smooth surface is in place with the best absorption qualities. Even if the unit compressive strength of Porete is low, nevertheless, the bracing for lateral stresses offered by the larger block of material in a tower type building would be excellent.

Table II gives a comparison of cost for floor slabs described in this paper.

CONCLUSIONS

1. Steel joists have proven their merit during the past ten years as an excellent material for secondary beams, where the occupation is light and the load is quiet, as in residences, apartments, dormitories, schools, office buildings, etc.

2. However, the manufacturers of this material must curb their enthusiasm for orders to the extent that superior construction and not volume of sales is the best argument with the designing engineer. Each and every design made by producers of all materials mentioned in this paper should have their designs approved by an independent engineer, who is not going to profit by the omissions of one kind and another.

3. Emphasis should be placed on details of each of these light materials described, to secure more fireproof construction. As our cities grow older and more prosperous, we will realize to a greater extent our tremendous waste due to fire losses, and will take adequate means to prevent the spread of fire in buildings. While some of the materials described in the preceding pages are not sufficient protection of the building, when a serious fire in the contents takes place they do not add any combustible material to the structure, as in wood construction.

4. The young designers with an inclination toward investigation should devote some of their time toward experimenting with newer mixtures of less heavy concrete. Some of the methods described in this article are too expensive to be practical. One method required a plant installation of \$250,000. The risk of obsolescence is so great that promoters will not take a chance. The writer believes approximate results may be accomplished by trapped air cells in some of our present waste products.

5. We have been wasteful in heavy dead weights added to our construction, and have excused this waste in the name of fireproofing. It is high time we "took count of stock" in this regard and ask ourselves if our construction problems have been solved in the best manner in our quest for less combustible buildings. Let each and every designer, whether a sales engineer or a consultant, realize he is a part of the oldest and most honorable craft, — namely, providing shelter for mankind. In future years will the owner appreciate more a few dollars saved by skimped construction, or an excellent structure, economically designed and honestly built? And will he have the supreme satisfaction expressed in Ruskin's lines:

Therefore, when we build, let us think that we build forever. Let it not be for present delights, nor for present use alone; let it be such work as our descendants will

thank us for, and let us think, as we lay stone on stone, that a time is to come when those stones will be held sacred because our hands have touched them, and that men will say as they look upon the labor and wrought substance of them, "See! This our fathers did for us."

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COSTS OF SCHOOL FLOORS

BY JOSEPH B. HARRIMAN *

(Presented at a meeting of the Designers Section of the Boston Society of Civil Engineers,
April 8, 1931)

IN connection with the preliminary design of two or three school-houses, we made a study this winter of current local actual costs of floors adaptable to fire-resistive school buildings.

FIRE-RESISTIVE FLOORS

Just a word, first, as to my use of the word "fire-resistive." The layman says "fireproof," the building codes say "first-class." The first word, "fireproof," has not been in favor with engineers and fire underwriting experts; the second word, "first-class," is in process of redefinition at the present time in connection with the code revision work now being done by committees in various cities. I think it is generally agreed that the new Boston code will make provision in some way or other for a type of construction between what the present code defines as "first-class," and what it defines as "second-class," construction. Whether this new type of construction will be a subdivision of the first class, or whether it will be an intermediate class, I have no way of knowing at the present time. I have become convinced, however, in connection with this study, and with a parallel study which others in our office have been making along fire-protection lines, that any type of construction which is capable of resisting at least what is known by fire protection engineers as a one and one-half hour fire will provide all the fire protection that a school building should require so far as any fire hazard from within the building is concerned. Accordingly, "junior beams" and "bar joists," protected below with $\frac{3}{4}$ -inch metal lath and plaster, and protected above with 2 inches of concrete, have been accepted in this study as "fire-resistive" floors, although they do not come under the present Boston Building Code as "first-class" construction.

The need of such a study as we have made is probably apparent

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to you all, due to the great discrepancy in claims as to cost made by the advocates of various types of floors, and due, also, to the fact that various contractors are more or less in the habit of using some rule-of-thumb method of estimating floor costs.

The actual study embraced three stages:

The first stage consisted of conferences with representatives of various manufacturers and the adoption of various designs which would be more or less satisfactory. You will agree that nothing is more meaningless than a cost estimate given by a representative of some company who has something to sell, when taken by itself. This does not in any way reflect upon the honesty of such representatives, some of whom are here tonight. There are "jokers" in practically all such estimates. Due to strong competition, their designs are apt to be on the ragged edge of good practice, if not below that edge; and even if they pass the Building Code, good practice frequently requires that the designs submitted by such representatives be improved, at an increase in cost. Each of these representatives with whom we worked, however, showed a spirit of hearty co-operation, many of them sending the data to their head office and submitting designs prepared by their chief engineers. We checked all these designs and modified them as we felt necessary.

The second stage was to submit these approved designs to four reputable contractors who had expressed a desire to work with us on this matter. An experienced contractor sees what I have called the "jokers" in a salesman's estimate. For example, a representative may argue enthusiastically about how much money can be saved, let us say, in form work if his type of floor is used. We gave each representative a chance to submit his arguments to each contractor. If he could not convince the contractor that such a saving was possible, or until such time comes that he is able to so convince him, such saving, if it does exist, will go into the contractor's pocket and not into the client's, and is therefore of no interest to us, as we are trying to find costs that will be reflected in bids to the client.

The actual estimates or figures submitted to us by the four contractors on the various types of floors were averaged, and if the figure submitted by any contractor varied considerably from the average figure, we called the fact to his attention, and gave him a chance to go over his estimates again, so that the actual final averages represent the cost of such type of floor in comparison with the other types in a much more accurate way than would have been the case had one person done all the estimating.

Table 1 shows cost prices obtained for certain of the types of floors studied, as applied to a 20-foot span.

You will note from this table that the two types of "steel joist" floors are the most economical, as was to be expected, followed by one-way pan floors. Hollow tile floors would make a better comparative showing in shorter spans, pan floors, perhaps, in longer spans.

A "grid" floor for a schoolroom is evidently not economical if a smooth plastered ceiling is required by the Building Committee. Con-

*TABLE 1. UNIT FLOOR COSTS AS ESTIMATED BY CONTRACTORS
(FIRE-RESISTIVE FLOORS, 50 LBS. LIVE LOAD, 20 FT. SPAN,
GRANULITHIC SURFACING)*

TYPE OF FLOOR	ESTIMATES (UNREVISED)					RANK
	1	2	3	4	AVG.	
"Barjoist", Plaster Ceiling	.543	.608	.560	.685	.60	1
"J & L", Plaster Ceiling	.623	.692	.689	.676	.67	2
One-way Pan, Permanent, Plaster Ceiling (b)	.728	.711	.664	.731	.71	3
Two-way Pan, (Grid), Exposed Ceiling	.694	.730	.697	.720	.71	4
One-way Pan, Removable, Plaster Ceiling	.774	.750	.757	.797	.77	5
Hollow Tile, no soffits, Plaster Ceiling (b)	.798	.786	.719	.939	.81	6
"Slagblok", Plaster Ceiling (a)	.702	.791	.777	1.020	.82	7
Hollow Tile, soffits, Plaster Ceiling	.819	.802	.758	.970	.84	8
Two-way Pan (Grid), Plaster Ceiling	.854	.892	.807	.920	.87	9
"Battledeck", 2" Concrete, Plaster Ceiling		.880	.869		.88	10
"J & L", 2" Gypsum Ceiling Plastered	.900	.893	.848	.903	.89	11
"Battledeck", 2" Gypsum Ceiling Plastered		1.020	1.029		1.03	12
Flat Arch, Plaster Ceiling	.959	.970	.980	1.312	1.06	13
(a) Not in accordance with Boston Code. Design not checked						
(b) Probable visible markings on ceiling						

sequently the selection or rejection of this type of floor will depend on a committee's approval of its appearance exposed without plaster. For panels more nearly square this type of floor and the "Slagblok" floor, which are especially adapted to two-way reinforcing, would make better comparative showings.

In removable one-way pan floors the added cost shown as compared to permanent pan floors is partly if not wholly due to our specification that the ceiling be dropped enough to clear the ribs, to obviate the disagreeable appearance that occurs when ribs show through the

ceiling as lines of darker color. This objection, as we all know, applies often to hollow tile floors without soffits, but the pan manufacturers have told us that they know of no such trouble with permanent pan floors, and it may be that our specification was unnecessary.

The "Slagblok" floor is permitted at present in Boston on the basis of load tests only, but may be permitted later without such tests if the new code permits tile to carry stress. In this case the hollow tile floors may be reduced slightly in cost also.

The "Battledeck" floor estimated was designed for us by the American Institute of Steel Construction, and has a total of 2 inches of concrete above the steel deck to put it on a par with the others in fire resistance. Mr. Ernest Adams, their New England engineer, told us in advance that the cost would be prohibitive for a school floor, but was interested to know just where it would stand in the scale.

The floors with 2-inch hung gypsum ceilings conform to the present Boston Building Code for first-class construction. In our opinion, however, for light occupancies, such as schools, this added protection is not necessary, and its added cost not justified.

Flat arch floors, we are informed, are still in price competition in other sections of the country. Their high cost as shown in this study is doubtless partly due to the fact that experienced arch setters are no longer available here. A Boston representative of this type of construction believes that if there were a call for a considerable amount of this type of floor its cost could be reduced about 20 cents per square foot.

In all the tables we have used 50 pounds live load for class rooms, and adopted granolithic surfacing merely for purposes of comparison.

In addition to the saving in cost which a certain type of floor might show, other factors enter into a wise selection. For example, if I am convinced that a steel joist floor, protected as indicated, is sufficient for a school building from a fire-protection standpoint, I may still have convictions as to its value in other lines. Among other factors I might mention that I believe it is time that earthquake-resistance should be duly considered and evaluated in any building design in this part of the country, as well as in California or Japan; and a School Building Committee might well vote a few thousand dollars more for a type of floor that provided a higher degree of safety from this standpoint.

The third stage in the study was perhaps as important as either of the others, for even the figures just presented are not conclusive in themselves. This third stage was to prepare another column which I have called the "increment." This increment is made up of several

elements, largely penalties, and when applied to the average figures of apparent costs made some types of floor look less attractive. Yet every increment was adopted after careful study and computation. It should be understood that the increments which were used apply only to wall-bearing school buildings two or three stories high above the basement, and that an entirely different set of increments would be in order in another type of building, such, for example, as a ten-story office building, or a five-story apartment house, or even a steel-framed school building.

One element that entered into this increment was floor thickness. Assuming that a given distance from floor to ceiling was specified, it appeared that every added inch of floor thickness when applied to added masonry of walls, etc., meant about 1 cent per square foot penalty against such type of floor. Another element was the fire insurance rate question. You may not be aware of the fact that you can build a "first-class" building according to the Boston Code and still be penalized by the insurance rating organizations, if your construction in some particular does not come up to their published standards; and, rightly or wrongly, — the question is too large to debate here, — they penalize steel joist construction quite heavily. We obtained figures from the New England Insurance Exchange on the insurance rates on one particular school building for which different types of floors and walls were under contemplation. Taking their lowest rate as the base, capitalizing at 6 per cent the added annual insurance premium for any type of floor which was penalized, and dividing the result by the number of square feet of floor involved, we found that certain types of construction which would be acceptable to us meant an actual added indirect cost to the owner as high as 5 cents per square foot on insurance premium alone. We took account, also, of the fact that concrete floors occupied actual space in the bearing walls which would have to be filled up with masonry at a rather high labor charge if joist construction were used, and the cost of such masonry filling added another small penalty against the joist floors. In a multi-storied or steel-framed building the same joist floors would have a very different "increment," and might show instead of a penalty a net "bonus," due to the very large saving in weight. In a two or three story building, however, where the design embraces bearing walls both on the exterior and along the corridors, and where foundation conditions are favorable, saving of floor weight has very little value.

Table 2 shows costs after the "increment" has been applied. In this table the order of economy is the same as in Table 1, except that

the "grid" floor with exposed ceiling has moved up to second place, exchanging places with "junior beam" construction, and nearly equaling the economy of "bar joist" construction. As before stated, however, a "grid" floor with exposed ceiling will be selected or rejected for other reasons than the few cents differential between it and its nearest competitors.

TABLE 2. UNIT FLOOR COSTS AS REVISED (FIRE-RESISTIVE FLOORS, GRANOLITHIC SURFACING)

TYPE OF FLOOR	UNREVISED ESTIMATES		INCREMENT (C)	REVISED ESTIMATES	
	COST	RANK		COST	RANK
"Barjoist", Plaster Ceiling	.60	1	.11	.71	1
"J & L", Plaster Ceiling	.67	2	.10	.77	4
Oneway Pan, Permanent, Plaster Ceiling (b)	.71	3	.03	.74	3
Two-way Pan, (Grid), Exposed Ceiling	.71	4	.02	.73	2
Oneway Pan, Removable, Plaster Ceiling	.77	5	.05	.82	5
Hollow Tile, no soffits, Plaster Ceiling (b)	.81	6	.01	.82	6
"Slagblok", Plaster Ceiling (a)	.82	7	.00	.82	7
Hollow Tile, soffits, Plaster Ceiling	.84	8	.02	.86	8
Two-way Pan (Grid), Plaster Ceiling	.87	9	.00	.87	9
"Battledock", 2" Concrete, Plaster Ceiling	.88	10	.02	.90	10
"J & L", 2" Gypsum Ceiling Plastered	.89	11	.13	1.02	11
"Battledock", 2" Gypsum Ceiling Plastered	1.03	12	.04	1.07	12
Flat Arch, Plaster Ceiling	1.06	13	.02	1.08	13
(a) Not in accordance with Boston Code. Design not checked					
(b) Probable visible markings on ceiling					
(c) Made up of various elements, including floor thickness, insurance penalty, etc. No credit here given for saving in weight, which would be a large factor in some types of buildings.					

WOOD JOIST FLOORS vs. FIRE-RESISTIVE FLOORS

While our study was primarily on fire-resistive floors, we later decided to include wood joist floors also. Since the previous studies were not concerned with the floor surfacing, but were intended only to show comparative structural costs, we had specified in each case a 1-inch granolithic surface. To compare the cost of fire-resistive floors, therefore, with wood joist floors it was necessary to put them all on the same basis of wood surfacing. We used the same care in the study of wood

joist floors as in the fire-resistive floors, and to make the comparison a true one, obtained from the same contractors figures for the difference in cost between a 1-inch granolithic surface and a wood surface consisting of a top floor of maple and an under floor and 2 inches of fill with wood screeds.

Table 3 shows the unrevised cost of wood joist floors in comparison with the five most economical types of fire-resistive floors. The costs of the latter have been increased 24 cents over the costs shown on Table 1, to cover the added cost of the wood surfacing. It will be

*TABLE 3. COMPARISON OF COSTS OF WOOD JOIST FLOORS AND
FIRE-RESISTIVE FLOORS (MAPLE FLOORING)*

<i>TYPE OF FLOOR</i>	<i>UNREVISED ESTIMATE OF COST (d)</i>
<i>Wood Joist Floor, Plaster Ceiling, Maple Flooring</i>	<i>.65</i>
<i>Fire-Resistive Floors:-</i>	
<i>"Barjoist", Plaster Ceiling, Maple Flooring</i>	<i>.84</i>
<i>"I & L", Plaster Ceiling, Maple Flooring</i>	<i>.91</i>
<i>One-way Pan, Permanent, Plaster Ceiling, Maple Flooring</i>	<i>.95</i>
<i>Two-way Pan (Grid), Exposed Ceiling, Maple Flooring</i>	<i>.95</i>
<i>One-way Pan, Removable, Plaster Ceiling, Maple Flooring</i>	<i>1.01</i>
<i>(d) No attempt is here made to apply an increment to these costs, as other matters such as incidental construction, insurance, etc. would have to be considered for any particular case. The unrevised figures shown above indicate a possible saving of from 3% to 7% of total cost of building, if other factors were equal.</i>	

noted that the unrevised costs of the fire-resistive floors, without wood surfacing, would apparently have been very closely equal to the cost of a wood joist floor with maple flooring.

The increment to be used in connection with wood joist floors is a very difficult one, and we did not attempt to apply any increment in this table. The two types of construction are not in the same class. Moreover, the scheme of masonry bearing walls along the corridors, which was used in the other designs, might, in the case of a second-class building, be abandoned in favor of stud partitions, and other changes might be made in the general design. If wood joist floors are used in a school building with masonry exterior walls, a certain degree

of consistency of design should be considered; for example, if the school committee should wish the first floor and the corridor walls to be of fire-resistive construction, the only saving would be in upper classroom floors and roof. Such saving might amount to only 2 or 3 per cent of the total cost of the building, and it is a very questionable economy in the light of lowering the class of the entire building. On the other hand, if, perhaps by the use of sprinklers, a second-class building could be designed which would show an actual saving of, say, 10 per cent of the total cost, it might be a very consistent saving. The use of wood joist floors and roof indicates a saving of from 3 to 7 per cent of the total cost of a building, which percentage would perhaps be greater or less when some particular case is studied.

PRIZES AWARDED BY BOSTON SOCIETY OF CIVIL ENGINEERS

DESMOND FITZGERALD MEDAL

THE Desmond FitzGerald medal, an endowed prize, is awarded for papers presented at meetings of the Boston Society of Civil Engineers and published in the JOURNAL of the Society. This prize is to be awarded annually unless the Board of Government shall decide that none of the papers presented during the year are of such a character as to merit the award.

With the assent and approval of the donor, the Society has assumed the responsibility for the payment in perpetuity of the Desmond FitzGerald medal.

Rules Governing the Award of the Desmond FitzGerald Medal

COMMITTEE ON AWARD

1. The Board of Government shall appoint annually, not later than its regular meeting in June of each year, three members of the Society, not members of the Board of Government, who shall form a committee to recommend the award of the prize.

2. The papers considered shall include all papers published by the Society during the year ending with the month of January.

3. The Committee on Award shall report its recommendation to the Board of Government at its February meeting, and the awards shall be made by the Board of Government.

4. The announcement of the awards shall be made at the annual meeting.

5. The Secretary of the Society shall act as Secretary to the Committee on Award, but shall have no vote or voice in its deliberations.

CODE OF RULES

THE DESMOND FITZGERALD MEDAL.—This medal was instituted and endowed in 1910 by Desmond FitzGerald, member and Past President of the Boston Society of Civil Engineers.

I. Competition for the medal of the Boston Society of Civil Engineers shall be restricted to members of the Society of all grades.

II. There shall be one bronze medal awarded as hereinafter provided. The dies therefor shall be deposited with the superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose.

III. All original papers presented to the Society by members of any class, and published by the Society during the year for which the medal is awarded, shall be open to the award, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society.

IV. The medal shall be awarded for a paper which shall be judged worthy of special commendation for its merit.

Awards of the Desmond FitzGerald Medal

- For 1911. Charles R. Gow, for paper, "Methods and Cost of Construction of Slow Sand Purification Works for the New Springfield, Mass., Water Supply."
- For 1912. Charles T. Main, for paper, "The Work, Aim and Conduct of the Engineer."
- For 1913. David A. Hartwell, for paper, "The Fitchburg, Mass., Intercepting Sewer."
- For 1914. Joseph R. Worcester, for paper, "Boston Foundations."
- For 1915. William S. Johnson, for paper, "Ground Water Supplies."
- For 1916. Dana M. Wood, for paper, "Power Estimates from Stream Flow and Rainfall Data."
- For 1918. Stephen DeM. Gage, for paper, "The Sanitary Control of Swimming Pools."
- For 1919. Edgar Sutton Dorr and Robert Spurr Weston, for their paper, "The Disposal of Sewage by Treatment with Acid."
- For 1920. Harrison P. Eddy, for paper, "Maximum Rates of Precipitation at Boston for Various Frequencies of Occurrence."
- For 1921. Harold K. Barrows, for paper, "Water Power Development in New England."
- For 1923. Arthur T. Safford, for paper, "The Amoskeag Manufacturing Company Hydro-Electric Development."
- For 1924. Arthur C. Eaton, for paper, "The New England Power Company — Davis Bridge Development."
- For 1925. Frank C. Shepherd, for paper, "The Preservative Treatment of Ties on the Boston & Maine Railroad."
- For 1926. Harry A. Hageman and Theodore B. Parker, for their paper, "The Bartlett's Ferry Hydro-Electric Development."
- For 1927. Dr. Charles Terzaghi, for paper, "Concrete Roads — A Problem in Foundation Engineering."
- For 1929. James W. Rollins, for paper, "Pier Construction for the Mid-Hudson Bridge at Poughkeepsie, N. Y."
- For 1930. H. B. Kinnison, for paper, "Stream Flow Data — Its Collection and Use."

SECTION PRIZE AWARDS

Sections of Boston Society of Civil Engineers

Sanitary Section, organized in 1904.

Designers Section, organized in 1920.

Highway Section, organized in 1924.

Northeastern University Section, organized in 1922.

Rules Governing Section Awards for Sanitary, Designers and Highway Sections

The Board of Government of the Boston Society of Civil Engineers voted on April 12, 1924, "to present a prize for a worthy paper given in each section by a member of that Section," the awards to be made under the following rules:

1. The Board of Government shall award annually in each section a prize for the best paper presented during the year, provided that paper is judged worthy of special commendation.
2. The Board shall appoint annually a Committee on Award for each section, to be composed of three members, one of whom shall be a member of the Committee on Award of the Desmond FitzGerald medal, the others shall be members of the particular section involved, and none shall be members of the Board of Government. The appointment shall be made not later than at its regular meeting in June. The Committee on Award shall recommend to the Board their selection of successful papers.
3. The papers considered shall include all original papers which are submitted in form suitable for publication, by members in all grades of the respective sections, and shall have been accepted by the Executive Committee of the Section or its approved agent, either for publication or for presentation at a meeting. All papers considered shall be presented at a meeting or published during the year ending with the month of January, and no paper shall be eligible which has received, or is to receive, any other award of the Society, or which has previously been contributed to any other association, or has appeared in print prior to its presentation to the section.
4. The Committee on Award shall report their recommendations to the Board of Government at its February meeting, and the awards shall be made by the Board of Government.
5. The announcement of the awards shall be made at the annual meeting.
6. The award shall consist of a book or books of a value not exceeding fifteen dollars, and shall be suitably inscribed on the flyleaf with the name

of the recipient, the name and date of presentation of the paper, and the name of the section, together with the fact that it was judged the most worthy paper presented in that section during that particular year. The inscription shall be in handwriting attested to by the President of the Society and the chairman of the Section. The Committee on Award shall select the book or books to be awarded, but may consult with the recipient as to his particular desires in the matter.

Section Awards

Sanitary Section

- For 1925. F. William Haley, for paper, "Recent Additions to the Sewerage System and Disposal Works of Framingham, Massachusetts."
 For 1926. Gordon M. Fair, for paper by G. M. Fair and C. L. Carlson, "Sludge Digestion — Reaction and Control."
 For 1928. Frank A. Marston, for paper, "Progress in Sewage Treatment Abroad."
 For 1929. Robert Spurr Weston, for paper, "Some Examples of Pollution of Streams by Industrial Wastes."

Designers Section

- For 1924. William D. Henderson, for paper, "Structural Design Features of a Hydro-Electric Development."
 For 1925. Barzillai A. Rich and William Walter Bigelow, for their paper, "Stresses in a Composite Member Subjected to Bending and Direct Stress."
 For 1926. Ray H. Lindgren, for paper, "Design of Details in Timber Structures."
 For 1927. Clarence E. Carter, for paper, "Repairs to the Folly Hill Reservoir of the Salem Water Supply, Salem, Mass."

The Board of Government adjudged that a paper presented at a meeting of the Designers Section in 1930 by Raymond A. Freeman and A. S. Gilman on "The Angular Rotation Method for the Analysis of Multiple Span Frames," although not conforming to the rules of award, be recognized by the award of a special prize consisting of books to each author.

Highway Section

- For 1926. LeRoy M. Hersum, for paper, "Structural Design of Concrete Roads."
 For 1929. Arthur W. Dean, for paper, "Massachusetts Highways."

Rules Governing Prize Awards for Northeastern University Section

The Board of Government voted on March 10, 1931, to revise the Rules Governing the Award of Section Prizes in order to provide specifically for the award of a prize to a member of the Northeastern University Section, as follows:—

1. The Board of Government of the Boston Society of Civil Engineers shall award annually in the Northeastern University Section a prize for an original paper prepared by a member of the Section and presented by the author during the year at a regular Engineering Conference meeting.
2. A committee of the faculty at Northeastern University shall present to the Committee on Award of the Boston Society of Civil Engineers two papers selected by the University at such a time as may be required.
3. The Committee on Award shall report its recommendation to the Board of Government at its February meeting, and the awards shall be made by the Board of Government.
4. The announcement of the awards shall be made at the annual meeting of the Boston Society of Civil Engineers.
5. The award shall consist of a book or books of a value not exceeding fifteen dollars; these shall be suitably inscribed with the name of the recipient, the name and date of publication of the paper, and the name of the Section, together with the fact that it was judged a paper worthy of special commendation. The inscription shall be signed by the President of the Society and the chairman of the Section. The Committee on Award shall select the book or books to be awarded, but may consult with the recipient as to his particular desires in the matter.
6. The winning paper may or may not be printed in the JOURNAL of the Boston Society of Civil Engineers at the discretion of the Publication Committee.

CLEMENS HERSCHEL AWARDS

In 1923 the late Clemens Herschel, a Past President and an honorary member of the Boston Society of Civil Engineers, presented to the Society a number of autographed copies of his book, entitled "Frontinus and the Water Supply of the City of Rome," with the request that the Board of Government should award one or more of these books as prizes for papers which have been particularly useful and commendable and worthy of grateful acknowledgment.

Awards

- For 1924. Almon L. Fales, for paper, "Odor Elimination;" and to Charles H. Pierce, for paper, "Flood Flows of New England Rivers."
- For 1925. Edward P. Hamilton, for paper, "The Development of the Science of Hydraulics;" and to Dr. Charles Terzaghi, for paper on "Modern Conceptions Concerning Foundation Engineering."
- For 1926. Earle B. Phelps, for paper on "Chlorination of Water and Sewerage;" to Albert J. R. Houston, for paper on "Some Observations on European

Water Power Practice;" and to D. B. Steinman and W. G. Grove, for joint paper on "The Design and Construction of the Florianopolis Bridge."

- For 1927. Prof. Charles M. Allen, for paper, "Water;" and to Dr. George H. de Thierry of the Technical University of Charlottenberg, Germany, for paper, "Application of Laboratory Research to the Study of Hydraulic Problems."
- For 1928. Dr. William Rudolfs, for paper, "Sludge Digestion;" and to Edward H. Cameron, for paper, "Engineering Features of a Modern Glass Bottle Plant."
- For 1929. William F. Uhl, for paper, "The Development of the Mongaup River."
- For 1930. Edwin A. Dow, for paper, "Hydraulic and Mechanical Features of Bellows Falls Hydro-Electric Plant of the New England Power System."

OF GENERAL INTEREST

COMMITTEE APPOINTED BY BOSTON SOCIETY OF CIVIL ENGINEERS TO STUDY THE REPORT OF THE NEW ENGLAND GOVERNORS' RAIL- ROAD COMMITTEE

The Board of Government of the Boston Society of Civil Engineers authorized President Harry E. Sawtell to appoint a committee to study and report upon the Report of the New England Governors' Railroad Committee.

This committee consists of Prof.

Charles B. Breed, Chairman, Lewis E. Moore, Prof. C. Frank Allen, Frank M. Gunby, and Frank B. Walker. This committee, with the addition of James P. Alexander, has also been designated as the committee of the Engineering Societies of Boston to study that report.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

MAY 20, 1931. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 7 P.M. by the President, Harry E. Sawtell. There were about 160 members and guests present. Previous to the meeting 120 members attended the usual buffet supper.

The President announced the death of Lester W. Tucker on March 24, 1931, a member since May 20, 1896; and of Henry Dickinson Woods on April 2, 1931, a member since April 15, 1885.

The Secretary announced that the following had been elected to membership by the Board of Government:

Grade of Member: Raymond A. Freeman,* Ernest F. Gallagher.

Grade of Associate: John F. Kennedy.

Grade of Junior: John L. Freiheit, Laughlin C. F. Macdonald, Freeman W. Towers.

The President then presented Mr. Clarence R. Bliss, Assistant Designing Engineer, New England Power Engineering and Service Corporation, who gave a talk on the "Fifteen-Mile Falls Lower Development."

The Fifteen-Mile Falls Lower Development, New England's largest hydro-electric development, is located on the Connecticut River in the towns of Munroe, New Hampshire, and Barnet, Vermont, about a mile and three-quarters above the mouth of the Passumpsic River. The main structures include the power plant and an earth dike on the New Hampshire

* Transfer from Grade of Junior.

bank of the river, a mass concrete retaining wall extending 500 feet upstream and 395 feet downstream along the New Hampshire side of the river channel, and a concrete non-overflow section of dam, about 170 feet high, at midstream, extending across the river to the Vermont shore and the spillway, which is located on the Vermont side of the river and is 850 feet long, varying in height from 20 to 85 feet.

The electrical energy will be generated at 13,800 volts, stepped up to 66,000 volts for local distribution, and to 220,000 volts for long distance transmission. The effective power is 140,000 kilowatts.

The outdoor switching stations are located on the New Hampshire hillside. These stations are one of the terminals of the high tension line tying this plant to the distribution network of the New England Power Association System.

Discussion of the paper was presented by Mr. Arthur C. Eaton, Hydraulic Engineer, New England Power Engineering and Service Corporation; William F. Uhl, Hydraulic Engineer, Chas. T. Main, Inc.; Irving B. Crosby, Consulting Geologist; and Prof. H. K. Barrows, Professor of Hydraulic Engineering, Massachusetts Institute of Technology.

The meeting adjourned at 9.10 P.M.

EVERETT N. HUTCHINS, *Secretary*.

Sanitary Section

MINUTES OF ANNUAL EXCURSION, JUNE 6, 1931, WOONSOCKET, RHODE ISLAND, SEWAGE TREATMENT WORKS

JUNE 6, 1931. — Annual Excursion. Thirty-five members and guests were met at the sewage pumping station at Woonsocket, Rhode Island, at 2.45 P.M. by Mr. J. H. White, Commissioner of Public Works, who with several of his staff conducted the party over the new municipal activated sludge sewage treatment plant, the first municipal plant of this type in New England.

The new plant consists of variable-speed vertical centrifugal pumps, mechanically cleaned, fine bar-screen, aerated skimming tank, self-cleaning pre-sedimentation basins, aerating tanks, final self-cleaning sedimentation basins, sludge digestion tanks and gas collectors, open and glass-

enclosed sludge drying beds, and effluent chlorinator, together with appurtenances for furnishing air, pumping sludge, and applying lime to the digesting sludge.

On this date the plant was operating at the rate of 3.5 million gallons daily. The effluent was being discharged upon the old intermittent sand filters.

The new plant has been in operation since April of this year.

GEORGE G. BOGREN, *Clerk*.

Designers Section

MAY 13, 1931. — The May meeting of the Designers Section was held in Chipman Hall and was a joint meeting with the Highway Section.

The meeting was called to order at 6.05 P.M. by Chairman Harsch of the Designers Section.

Mr. Benjamin A. Loveland, Assistant Engineer of the Boston Transit Department, then spoke on the structural design of the new East Boston Tunnel. He touched upon the history and general aspects of the tunnel, as well as upon the design and details of the tunnel itself. His talk was illustrated with several slides.

During the discussion, Mr. Loveland answered several questions put by members and guests. Mr. Francis Donaldson, Chief Engineer of Silas Mason Company, Inc., contractor on the building of the tunnel, added to the discussion with some remarks based on his experience in building tunnels.

The meeting was adjourned at 7.25 P.M.

There were 108 persons present.

RAYMOND A. FREEMAN, *Clerk*.

Northeastern University Section

MAY 21, 1931. — The Northeastern University Section of the Boston Society of Civil Engineers held the last meeting of the year on Thursday, May 21, 1931, in Room 18H, Huntington Building. The meeting was called to order by Chairman John H. Lowe, and the report of the Secretary was read and approved. The remainder of the business was the election of officers for the ensuing year, the following being elected:

Chairman — John B. Komich.
 Vice Chairman — Kenneth H. Gilson.
 Clerk — Richard D. Murphy.
 Executive Committee — John H. Lowe,
 John W. Copithorne.

Due to the absence of many men from Division A it was decided that the Executive Committee should elect the third member of the committee at the first meeting.

At the close of the business meeting Chairman Lowe introduced the first speaker of the evening, Mr. A. E. Sanderson, a graduate of Northeastern, in the class of 1926, who is employed as chief draftsman by the Boston Bridge Works. He gave a very interesting talk on the design and erection of the steel work on the new Tyngsborough bridge across the Merrimack River.

The other speaker, Mr. A. E. Harding, is also a Northeastern graduate, of the class of 1922. He is employed by Simpson Brothers Company, and is the superintendent of construction on the Tyngsborough bridge. Mr. Harding explained many of the difficulties encountered in the construction of the bridge, and showed how much of the concrete work was done in the winter in the intense cold. At the close of his talk a question period was in order.

After all present had expressed their thanks to Mr. Sanderson and Mr. Harding for their interesting talks, refreshments were served and the meeting adjourned at 9.45 P.M.

There were 22 members present.

RICHARD D. MURPHY, *Clerk.*

APPLICATIONS FOR MEMBERSHIP

[June 20, 1931]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at

a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

STANDKE, MAX PAUL, Brighton, Mass. (Age 43, b. Germany.) Graduate of Northeastern University in 1920 and received degree in 1921. From July, 1920, to April, 1921, employed by Daniel L. Shepard as field engineer and time keeper; from December, 1922, to March, 1923, with the Aberthaw Company as draftsman; from March 19, 1923, to August 4, 1923, employed by the United Fruit Company as detailer; from August 6, 1923, to September 20, 1924, with Aberthaw Company, as detailer; from September 22, 1924, to September 7, 1926, with Morton C. Tuttle Company, as detailer, designer and squad chief; from September 9, 1926, to December 19, 1930, with the Concrete Steel Company, as chief engineer; from January 17, 1931, to date, with Vappi & Ferguson, contractors, as estimator, sales engineer and construction supervisor. Refers to O. B. Brown, Erwin Harsch, G. E. Meyer, D. E. Rockwell.

ADDITIONS

Members

ERNEST F. GALLAGHER, 11 Beacon Street, Boston, Mass.
 JOHN F. KENNEDY, 80 Powder House Boulevard, Somerville, Mass.

Juniors

ROGER S. BROWN, 88 Oakwood Avenue, Lynn, Mass.
 JOHN L. FREIHEIT, 9 Long Hill Avenue, Shelton, Conn.

BOSTON SOCIETY OF CIVIL ENGINEERS

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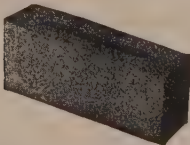
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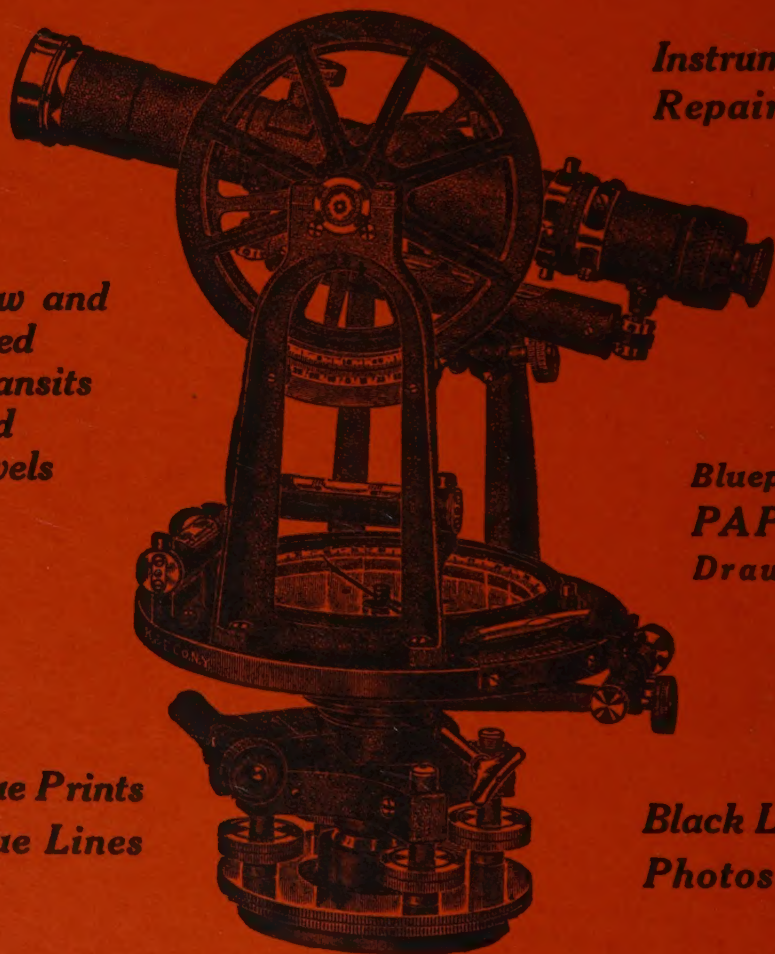
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